hydrology

Editorial

Flood Early Warning and Risk Modelling

Marina Iosub [1,2,*] and Andrei Enea [2,*]

1 Integrated Center of Environmental Science Studies in the North Eastern Region—CERNESIM, Sciences Department, Interdisciplinary Research Institute, Alexandru Ioan Cuza University of Iași, 700506 Iași, Romania
2 Department of Geography, Faculty of Geography and Geology, Alexandru Ioan Cuza University of Iași, 700505 Iași, Romania
* Correspondence: marina.iosub@uaic.ro (M.I.); andrei.enea@uaic.ro (A.E.)

Citation: Iosub, M.; Enea, A. Flood Early Warning and Risk Modelling. *Hydrology* **2022**, *9*, 57. https://doi.org/10.3390/hydrology9040057

Received: 29 March 2022
Accepted: 29 March 2022
Published: 31 March 2022

1. Introduction

The evolution of mankind during the last 2 centuries has generated an ever growing thrive for increased production, for the need to create novel means to generate energy and for society to change into a more consumerism-oriented version. All of these aforementioned arguments induce repeated and frequently irreversible repercussions on nature, and through constant alterations of the environment, significant global climate changes have been observed especially in the most recent times. During the last half of the century, all of these climatic changes have induced, as direct effects, the exponential rise in the number of natural disasters, and this increase is also emphasized by the ever-growing intensification of these phenomena, with devastating effects [1]. Out of all these extreme natural phenomena, floods are statistically considered some of the most damage-inducing, with an ever-more frequent recurrence time period, and can originate from fluvial sources, from extreme torrential rainfall, from coastal floods, or even due to underground causes. On a global scale, out of the entirety of registered events that took place since 1900, floods account for 25% of the events that occurred since 1900, 38% of the events registered since 1960, and 45% for events that took place since 2000 [2]. The population affected by this type of risk has dramatically decreased since the 1960′s, but the economic damages from floods, as a shared portion of the GDP at a global level, has risen from 0.02% (during the timespan between 1960–1969), up to 0.05% (between 2010–2019) [3]. The economic implications (costs of infrastructure, insurances, and even social-related issues) induced on the local communities are expected to increase even more in the following years, due to the expansion of the urban built-up areas, economic growth, and especially climate change [4,5].

The fact that natural phenomena, such as floods, induce tremendous amounts of damage, both from an economic and social perspective, has determined scientists to address this issue, and to search for potential solutions to identify areas, exposed to flood risk. In order to help mitigate this, multiple mathematical modelling algorithms were developed, with a variety of functions, such as calculating flow rate values, estimating possible recurring flow rates, mapping of flood risk, generating scenarios related to flood extent layers, warning and delay times for flash floods etc. [6,7]. Most of the aforementioned were mainly developed during the last 5 decades, justified by the increase in computational capabilities and in interest towards mitigating the negative impact of future events [2,3]. The main, general purpose they serve, is to describe the manner in which a drainage basin responds to sudden changes in flow rates, the increased values in torrential rainfall and estimate as precisely, as possible, the runoff, or even the groundwater related parameters, if required. Another aspect flood models address is the probability extent of floods along the main channel and floodplain for the main, collector river.

In order to mathematically model a flood event or simulation, significant temporal resources and labor have to be dedicated towards generating and validating the final results, therefore raising numerous technical challenges, associated to the complete characterization and cartographic representation of several physical and hydrodynamic parameters, such as: the relationship between rainfall and runoff, the heterogenic distribution of precipitation, the morphometric and pedological aspects in the study area etc. The more these parameters are better calibrated, the significantly better the final results related to the hydrological risk are, in accordance with the in-field situation [8,9]. Recent progress in the modern techniques, based on long, representative datasets are related to the increased availability of these kinds of methods, in comparison to the classic hydrodynamic analysis methodologies, which aid in the real-time forecasting of flood events. Novel detection systems (such as remote sensing techniques), in relation to modern data acquisition means, and backed by experimental techniques, provide new opportunities for calibration, validation, testing and improving the flood models [10–12].

The heterogenic manner through which the issue of flood risk is addressed, at the scientific, quantifiable level has determined us to compile a Special Issue which would promote publications that address flood analysis and apply some of the most novel inundation prediction models, as well as various hydrological risk simulations related to floods, that will enhance the current state of knowledge in the field as well as lead toward a better understanding of flood risk modeling. Furthermore, the current Special Issue will address the temporal aspect of flood propagation, including alert times, warning systems, flood time distribution cartographic material, and the numerous parameters involved in flood risk modeling.

2. Contributed Papers

The current Special Issue has managed to compile a total number of 6 published papers, with topics varying significantly, from the application of hydrological models specific to river valleys, to the study of entire drainage basins, by using 1D methods of analysis, or even 2D methods, with the help of virtual machines, and statistical data processing techniques, related to flood events and last but not least, flood early warning systems.

The article "*Towards Coupling of 1D and 2D Models for Flood Simulation—A Case Study of Nilwala River Basin, Sri Lanka*" by Dhanapala, L.; Gunarathna, M.H.J.P.; Kumari, M.K.N.; Ranagalage, M.; Sakai, K.; Meegastenna, T.J. describes the coupling method of two hydraulic models, in order to mathematically simulate floods on the valley of Nilwala River, in Sri Lanka. The methods used are HEC-HMS for the 1D analysis, while for 2D hydrological modelling, the method applied is iRIC. The model has been validated and calibrated using data from 3 selected events that have taken place during 2017–2019-time frame. The generated results have been validated to have an overall accuracy of 81.5%. Considering the novelty of the applied methodology, the authors have proposed that this method should be applied on more recorded hydrological events, in order to help emphasize the forecasting capabilities of the model [13].

One of the most recent large-scale hydrotechnical issues of current times is related to dams, and their potential risk to fail catastrophically. Considering that water resources are an ever-increasing global issue, governments have looked for different types of solutions to identify and prevent dam failure. The severity of the topic is emphasized by the fact that most current dams have been built at the beginning of the 20th century, which, correlated to the generalized state of degradation of most dams, corresponds to the continuous aging of these types of constructions. The current study "*Flood Mapping from Dam Break Due to Peak Inflow: A Coupled Rainfall–Runoff and Hydraulic Models Approach*" by Tedla, M.G.; Cho, Y.; Jun, K. addresses the dam break simulation of Kesem Dam, from Ethiopia, using the coupling 1D rainfall-runoff method HEC-HMS, which was used to predict flood volume, peak rates, and the runoff hydrograph, as well as the 2D hydraulic model HEC-RAS, used to simulate a piping dam break. Final results indicate the predisposition of the dam to flood risk through partial or complete breaking, for flow rates corresponding to recurrence periods between 100–200 years. The resulting maps from the 2D simulations aid in the identification of risk exposed areas downstream of dams [14].

For this particular study: "*Hydrological and Hydraulic Flood Hazard Modeling in Poorly Gauged Catchments: An Analysis in Northern Italy*" by Aureli, F.; Mignosa, P.; Prost, F.; Dazzi, S., a method for hydraulic 2D simulation has been applied, through the PARFLOOD algorithm, with the purpose of generating a flood hazard map in the poorly gauged drainage basins, with the study area located along the Chiavenna river valley in Italy. The article is divided into two methodological sections: in the first part, there is an analysis of the regional flood frequency from where the synthetic design hydrographs are derived, which are also imposed as upstream boundary conditions for 2D modeling. In the second part, 2D flood simulations are performed for 2 scenarios: a real one, in which 20 bridges are taken into account as cross sections; and a hypothetical one, in which bridges are not taken into account. The 20 sections have a role in indicating whether or not they influence the flood manifestation, depending on the way in which the bridges are dimensioned and located across the riverbed. Therefore, it was concluded that many of them influence the flood depth and the extent of flooded areas upstream of the bridges. The final results are the more important, the easier they are to be included in the design of road infrastructure and hydrotechnical builds for civil protection [15].

Understanding how floods manifest introduced the need to create models that aid in the efficient taking of decisions during the early stages of flood occurrences, or even before they manifest in the inhabited areas. The current study "*Flood Early Warning Systems Using Machine Learning Techniques: The Case of the Tomebamba Catchment at the Southern Andes of Ecuador*" by Muñoz, P.; Orellana-Alvear, J.; Bendix, J.; Feyen, J.; Célleri, R. addresses the comparative processes and results for 5 machine learning algorithms designed to simulate the flood water quantity that is associated to runoff due to short term floods, inside mountainous drainage basins of small or medium sizes. The models have been tested to emphasize the results in a clear, easily understandable form, by any non-expert person, in 3 categories (No-Alert, Pre-Alert and Alert). One of the suggested limitations of the applied methodology is that it offers very good performance only for the up to the 6-hour limit for lead times for forecasting result, as generated by the algorithms [16].

In the context of ever more frequent catastrophes and exposure of society to their impact, the need to differentiate between forecasting and nowcasting gathers more and more attention. Furthermore, the need to quickly and efficiently disseminate information regarding the manifestation of floods has determined scientists to develop and apply increasingly more complex simulation models. The HAND model has been applied in representative areas in Iowa in the article "*Real-Time Flood Mapping on Client-Side Web Systems Using HAND Model*" by Hu, A. and Demir, I., and have managed to prove the high dependability and efficiency of this model, especially when paired with web-platforms. Local authorities can use this approach to identify the areas exposed to flood risk, without requiring trained personnel to interpret scientific data, during torrential events, resulting in floods. Finally, one of the main advantages of this method is the minimal usage of datasets originating from external sources [17].

Catastrophic events have always had a two-sided approach, between researchers, on one side, and the target population, on the other side, therefore implying the need to quickly disseminate useful information via an easily accessible platform. ESRI StoryMaps provides such a possibility, as proved by the authors Oubennaceur, K.; Chokmani, K.; El Alem, A.; Gauthier, Y. of the study "*Flood Risk Communication Using ArcGIS StoryMaps*". For this particular study, a StoryMap has been generated in the drainage basin of Petite-Nation River, which suffers from flood damage on a frequent basis. Both vector and raster data has been integrated into the StoryMap, to more accurately represent the on-site situation, on a high level of detail. As a case study, the manuscript emphasizes the current flood-related situation, regarding risk management, but also includes predictive data which is related to future climate change [18].

3. Conclusions

The current Special Issue regarding Flood Early Warning and Risk Modelling, has successfully addressed different approaches of studying the way that flash floods manifest in the differently-sized drainage basins. Furthermore, these diverse papers have used 1D and 2D modelling methods, as well as comparative analysis between several machine learning algorithms, or hydraulic models, such as HAND model, which uses more morphometric based parameters. The emphasized has been also put on disseminating information on web-based virtual platforms, such as StoryMaps.

Author Contributions: The two Guest Editors (M.I. and A.E.) equally shared the work of soliciting, editing, and handling the contributions made to this Special Issue. All authors have read and agreed to the published version of the manuscript.

Funding: The creation of this Special Issue did not receive external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to acknowledge the efforts of all authors that contributed to the Special Issue.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. European Commission. Directorate-General for Environment, Impact of Climate Change on Floods: Survey Findings and Possible Next Steps to Close the Knowledge and Implementation Gap: Final a Survey Based Study, Publications Office, 2021. Available online: https://data.europa.eu/doi/10.2779/932572 (accessed on 15 March 2022).
2. EM-DAT. *The Emergency Events Database*; Université Catholique de Louvain (UCL)-CRED: Brussels, Belgium, 2016. Available online: www.emdat.be (accessed on 15 March 2022).
3. Our World in Data. *Natural Disaster*; Global Change Data Lab: Wales, UK, 2014. Available online: https://ourworldindata.org (accessed on 20 March 2022).
4. Liu, H.; Wang, Y.; Zhang, C.; Chen, A.; Fu, G. Assessing real options in urban surface water flood risk management under climate change. *Nat. Hazards* **2018**, *94*, 1–18. [CrossRef]
5. Ridolfi, E.; Mondino, E.; Di Baldassarre, G. Hydrological risk: Modeling flood memory and human proximity to rivers. *Hydrol. Res.* **2021**, *52*, 241–252. [CrossRef]
6. Enea, A.; Urzica, A.; Breaban, I.G. Remote sensing, GIS and HEC-RAS techniques, applied for flood extent validation, based on Landsat imagery, LiDAR and hydrological data. Case study: Baseu River, Romania. *J. Environ. Prot. Ecol.* **2018**, *19*, 1091–1101.
7. Iosub, M.; Minea, I.; Chelariu, O.E.; Ursu, A. Assessment of flash flood susceptibility potential in Moldavian Plain (Romania). *J. Flood Risk Manag.* **2020**, *13*, e12588. [CrossRef]
8. Jain, S.K.; Mani, P.; Jain, S.K.; Prakash, P.; Singh, V.P.; Tullos, D.; Kumar, S.; Agarwal, S.P.; Dimri, A.P. A Brief review of flood forecasting techniques and their applications. *Int. J. River Basin Manag.* **2018**, *16*, 329–344. [CrossRef]
9. Huţanu, E.; Mihu-Pintilie, A.; Urzica, A.; Paveluc, L.E.; Stoleriu, C.C.; Grozavu, A. Using 1D HEC-RAS Modeling and LiDAR Data to Improve Flood Hazard Maps Accuracy: A Case Study from Jijia Floodplain (NE Romania). *Water* **2020**, *12*, 1624. [CrossRef]
10. Mei, Y.; Anagnostou, E. A hydrograph separation method on information from rainfall and runoff records. *J. Hydrol.* **2015**, *523*, 639–649. [CrossRef]
11. Zhou, S.; Wang, Y.; Li, Z.; Chang, J.; Guo, A. Quantifying the Uncertainty Interaction between the Model Input and Structure on Hydrological Processes. *Water Resour. Manag.* **2021**, *35*, 3915–3935. [CrossRef]
12. Falter, D.; Dung, N.V.; Vorogushyn, S.; Schröter, K.; Hundecha, Y.; Kreibich, H.; Apel, H.; Theisselmann, F.; Merz, B. Continuous, large-scale simulation model for flood risk assessments: Proof-of-concept. *J. Flood Risk Manag.* **2016**, *9*, 3–21. [CrossRef]
13. Dhanapala, L.; Gunarathna, M.H.J.P.; Kumari, M.K.N.; Ranagalage, M.; Sakai, K.; Meegastenna, T.J. Towards Coupling of 1D and 2D Models for Flood Simulation—A Case Study of Nilwala River Basin, Sri Lanka. *Hydrology* **2022**, *9*, 17. [CrossRef]
14. Tedla, M.G.; Cho, Y.; Jun, K. Flood Mapping from Dam Break Due to Peak Inflow: A Coupled Rainfall-Runoff and Hydraulic Models Approach. *Hydrology* **2021**, *8*, 89. [CrossRef]
15. Aureli, F.; Mignosa, P.; Prost, F.; Dazzi, S. Hydrological and Hydraulic Flood Hazard Modeling in Poorly Gauged Catchments: An Analysis in Northern Italy. *Hydrology* **2021**, *8*, 149. [CrossRef]

16. Muñoz, P.; Orellana-Alvear, J.; Bendix, J.; Feyen, J.; Célleri, R. Flood Early Warning Systems Using Machine Learning Techniques: The Case of the Tomebamba Catchment at the Southern Andes of Ecuador. *Hydrology* **2021**, *8*, 183. [CrossRef]
17. Hu, A.; Demir, I. Real-Time Flood Mapping on Client-Side Web Systems Using HAND Model. *Hydrology* **2021**, *8*, 65. [CrossRef]
18. Oubennaceur, K.; Chokmani, K.; El Alem, A.; Gauthier, Y. Flood Risk Communication Using ArcGIS StoryMaps. *Hydrology* **2021**, *8*, 152. [CrossRef]